De-Coupled Solid Oxide Fuel Cell Gas Turbine Hybrid (dFC-GT)

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Project Vision

The pressurized SOFC-GT cycle offers high efficiency at design conditions, but presents significant challenges for off-design operation. Our project is validating an alternative system arrangement which could maintain the fast-response capability of the turbine and the high efficiency of the SOFC. The de-coupled system may be viable as a retro-fit of existing turbine systems, lowering development costs.

Project Overview

Fed. funding:	$0.75M
Length	24 mo.

Team member	Location	Role in project
Washington State University	Pullman, WA	Project lead, SOFC testing
Saint-Gobain	Northboro, MA	SOFC stack production and post-mortem analysis
Capstone Turbines	Van Nuys, CA	Micro-turbine testing with oxygen generator

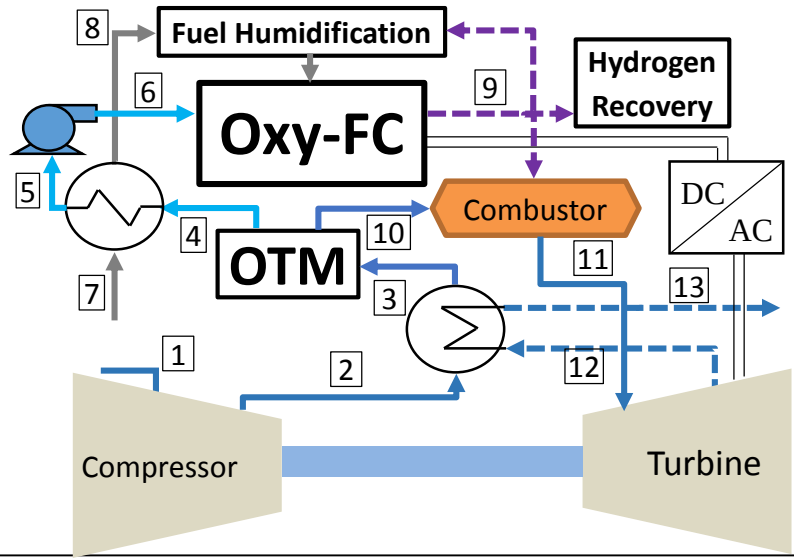
Context/history of project

The PI has a history of working with Capstone Turbines on fuel cell gas turbine hybrids. Saint-Gobain is a new partner with an innovative all ceramic stack that offers advantageous for the proposed pressurized oxygen cathode and internally reforming anode concept.

The project was envisioned as an alternative solution to previous challenges with dynamic control of SOFC-GT hybrids

Innovation and Objectives

Innovation: An oxygen conducting ceramic separates oxygen from the turbine air stream. A pump controls oxygen separation independent of the turbine air flow. The fuel cell reacts natural gas and oxygen, converting waste heat into hydrogen through internal reforming. The hydrogen supplements fuel provided to the turbine.



Task outline, technical objectives

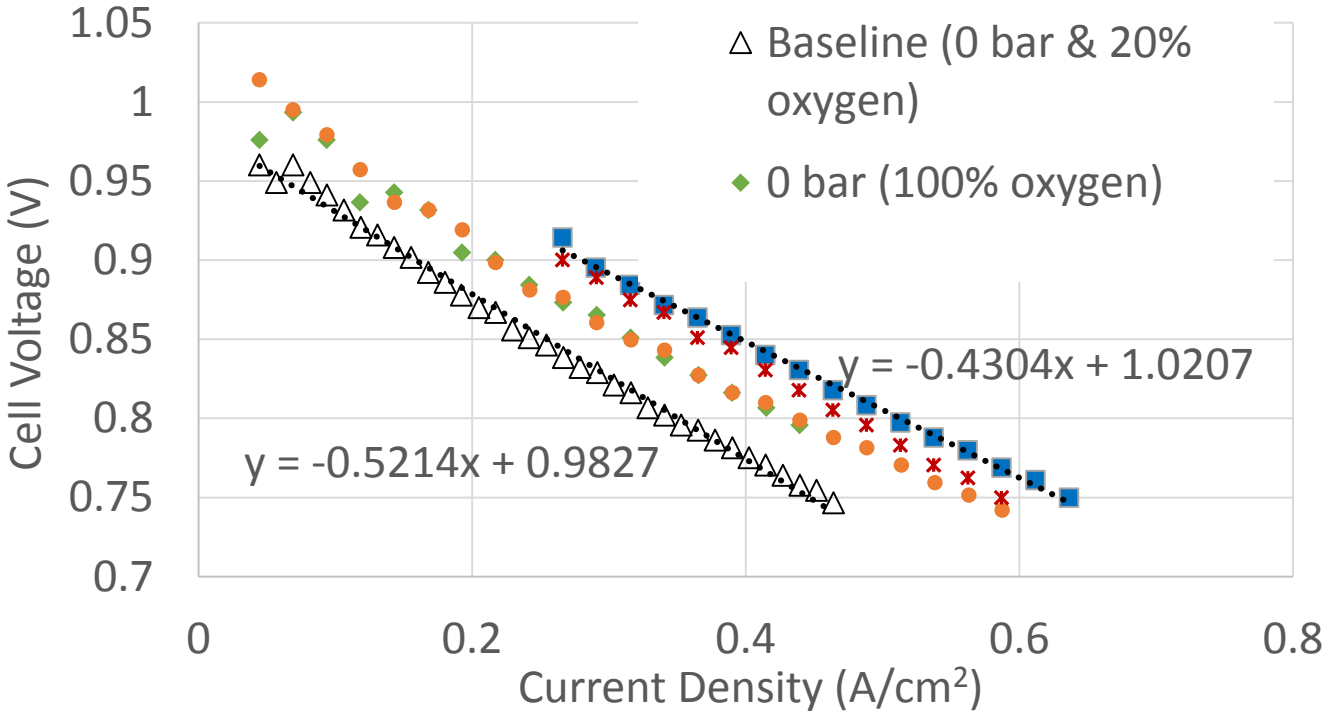
1. Operate single cell SOFC at up to 10 bar
2. Operate with 100% oxygen cathode
3. Sustain thermo-neutral operation with internal reforming
4. Test oxygen production with mGT integrated OTM
5. Evaluate all ceramic SOFC stack under dFC-GT conditions

Tech-to-Market objectives

- Develop as retro-fit of existing turbine generators
- Impacted air quality regions with need for fast responding power.
- Novel ceramic stack processing

Update # 1: Successes

- Tested single-cells (10cm X 10cm) at 10 bar with 100% O_2
  - 50/50 H_2/N_2 fuel

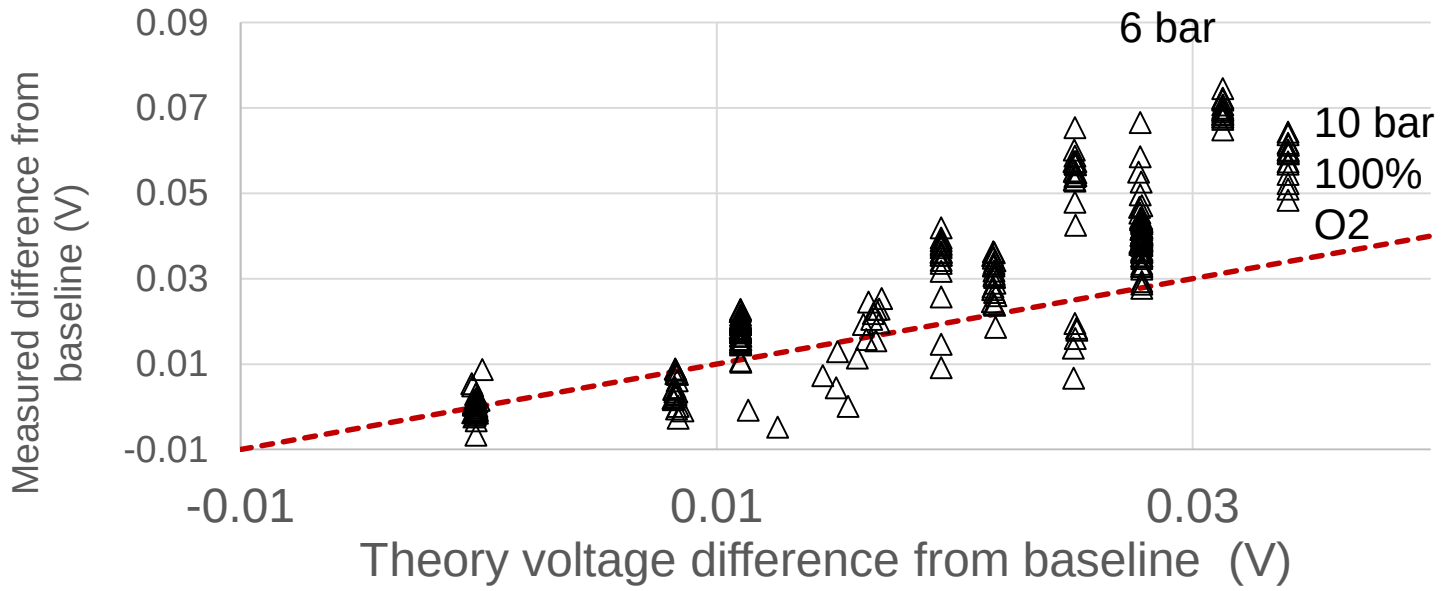


60% power improvement at 0.85V

- Patent under examination for de-coupled SOFC-GT hybrid
- New provisional patent filed for VYSZion material/manufacturing/system

Update # 1: Successes

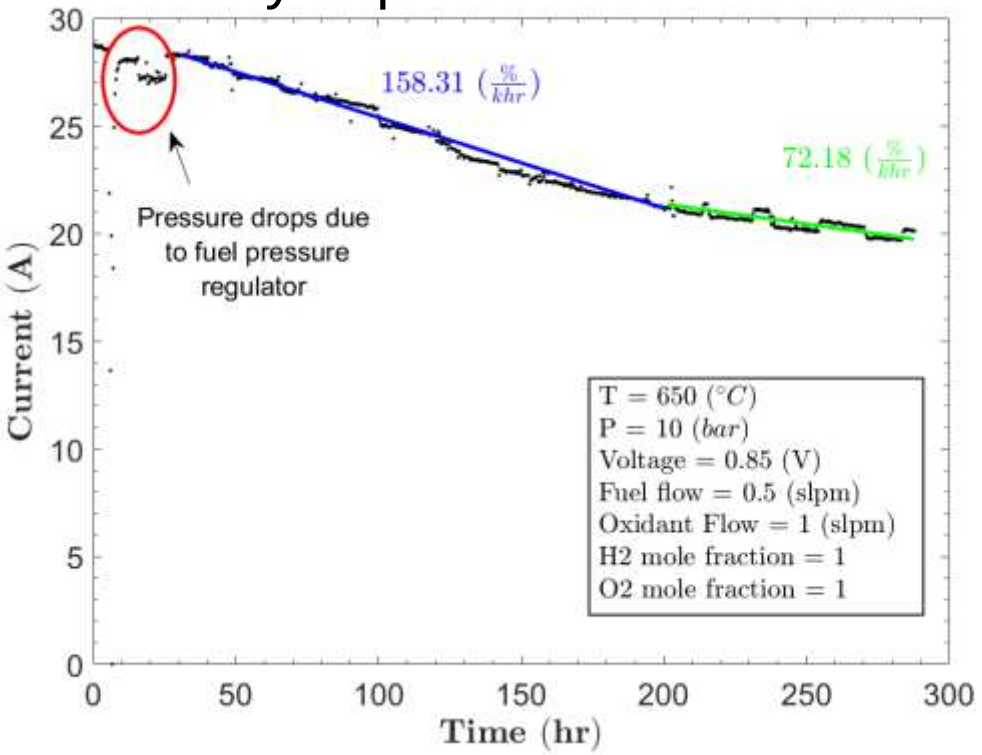
- Improvement cannot be solely explained by bulk operating conditions impact on Nernst potential, ASR is decreasing!
  - Better diffusion of O2 to reaction sites? Lower activation energy?
  - Unknown why 6 bar is better than 10 bar



- Developed low-cost impedance spectroscopy device for large area (low impedance) electrochemical cells using passive load excitation

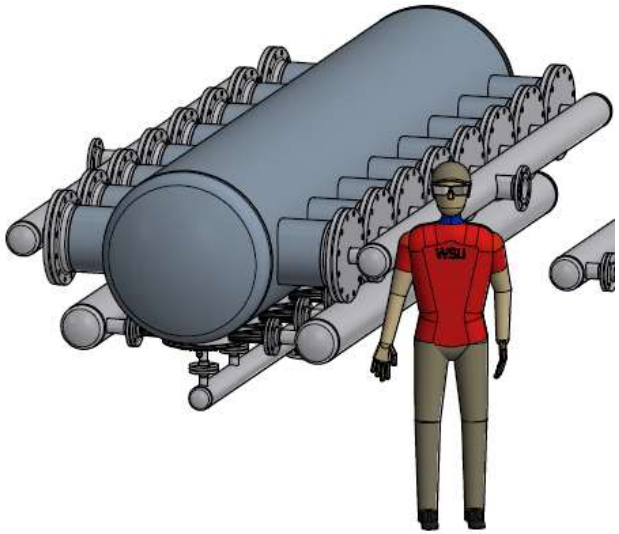
Update # 2: Challenges

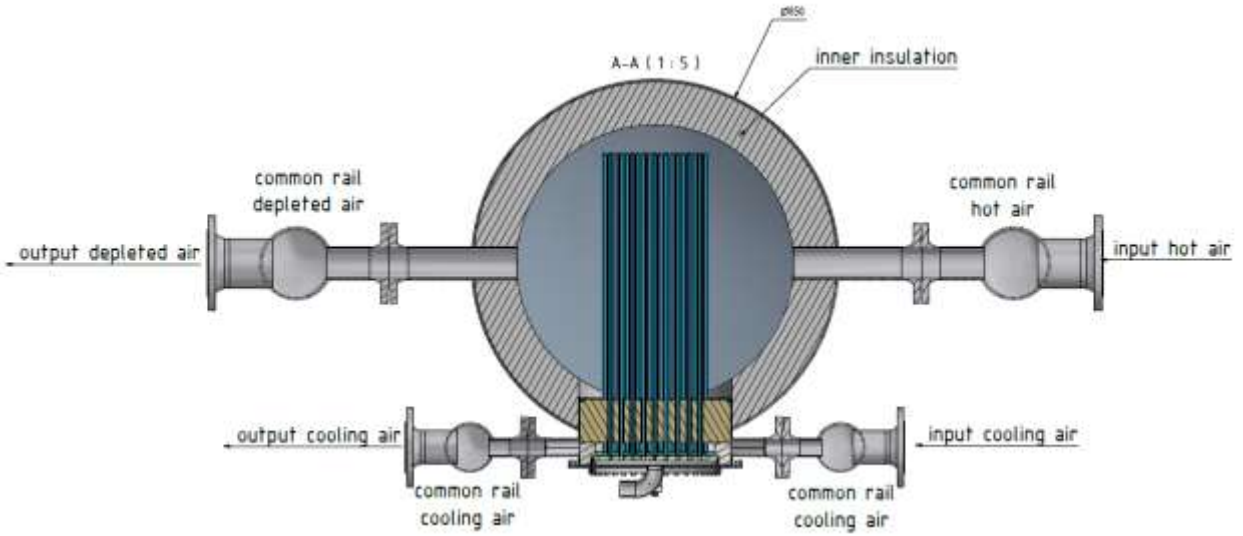
- Unacceptable degradation
  - Due to pressure or hot metal in test apparatus?
- MFC failure due to poor quality DI water in lab building
  - 2-months for Bronkhurst to repair & return MFC
  - Using better DI water from Chemistry department
  - Using ceramic base plate
- Coking with methane due to steam condensing between humidifier and furnace
  - Re-design steam supply: replace insulation with PID controlled heating tape top-down gravity assisted flow



Update # 2: Challenges

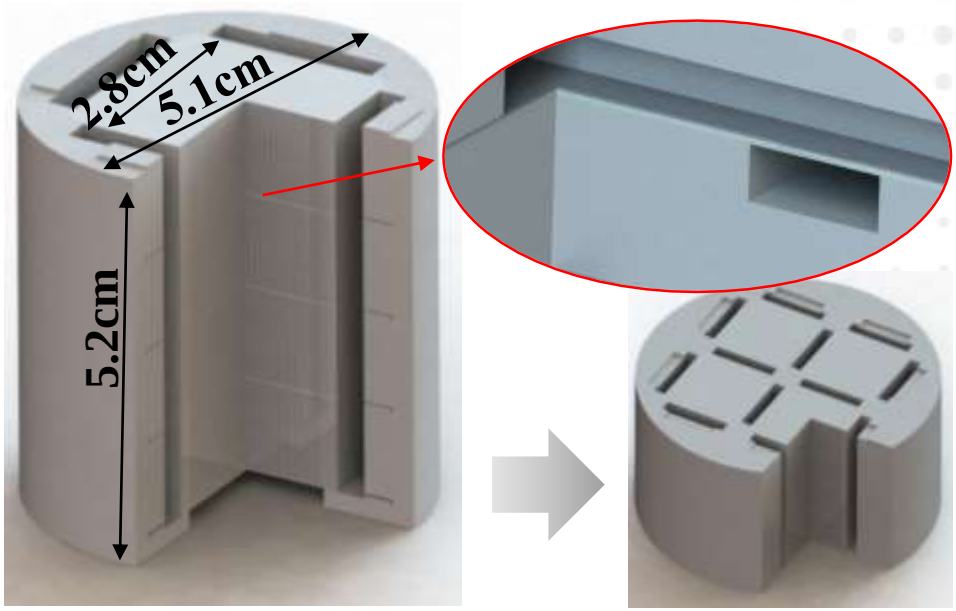
- Oxygen membrane supplier
  - Design requirement for high pressure cooling air flow
  - Size of tubular system is untenable for integrated system
  - Developing in-house MEIC material and membrane design





Update # 3: Visions

- How power dense can the SOFC get at pressure?
- Positive reinforcement with thinner repeat-units
  - 200µm to 400µm per repeat unit?
- Repeat-unit height ultimately limited by gas flow through micro-channels
  - 50µm channel ~10psi drop at 20 bar



120-240 cells
~0.5kW to 1kW
ASR = 0.4 Ohm-cm^2

Update # 3: Visions

- Micro-channels formed through material burnout
  - Need electrode & interconnect materials stable in oxidizing environment at 400°C
- High pressure system packaging: